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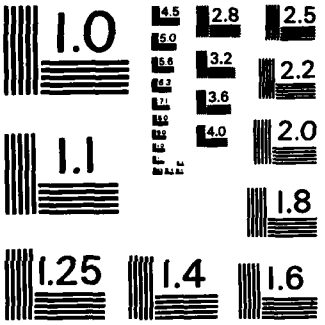

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The primary Purpose of the conference was to bring together scientists and engineers concerned with the mechanical properties of finely structured materials with scientists interested in the structure and properties of interfaces. Many of the participants indicated that they had developed new ideas which they intended to pursue in the coming months. This is regarded by most as the primary benefit of the Gordon Research Conference.

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FINAL REPORT

AFOSR GRANT (85-0219) FOR THE SUPPORT OF THE
1985 GORDON RESEARCH CONFERENCE ON PHYSICAL
METALLURGY

"ROLE OF INTERFACES IN DEFORMATION AND STRENGTHENING"

Submitted to

Air Force Office of Scientific Research
Division of Research Grants, Building 410
Bolling AFB, Washington, D.C. 20332

Attention: Dr. Alan H. Rosenstein

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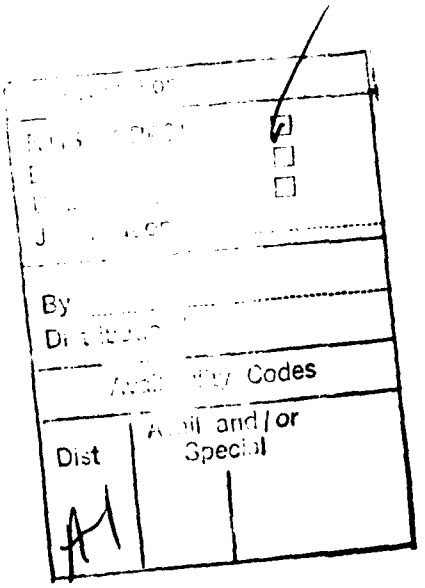

September, 1985

INTRODUCTION

The 1985 Gordon Research Conference on Physical Metallurgy was held 5-9 August 1985 at Holderness School in Plymouth, New Hampshire. The conference topic was "Role of Interfaces in Deformation and Strengthening". An AFOSR grant was made to the Gordon Research Conference to partially cover the travel and registration costs of some of the speakers and chairmen. A grant of $15,000 was made for this purpose. Of this total, $5,000 each was provided by AFOSR, ARO (150-85) and ONR (N0001485 RCM 2409). In this report we give a brief description of the conference and describe some of the highlights of the meeting.

CONFERENCE DESCRIPTION

The primary purpose of the conference was to bring together scientists and engineers concerned with the mechanical properties of finely structured materials with scientists interested in the structure and properties of interfaces. The joining of these two groups was expected to lead to the development of new ideas and to the cross-fertilization of these ideas. Following the tradition of previous Gordon Conferences, a relatively small number of speakers were invited to make presentations to the conference. The primary purpose of these talks was to stimulate discussion and thought on the topic of interfaces in deformation and strengthening. A copy of the program of speakers and chairmen is appended to this report.

A poster session was also held during the conference so that some of the participants could present their research results. A list of the poster presentations is also appended to this report.

The conference attracted participants from a wide variety of institutions

and countries. The list of participants appended to this report shows that a total of 96 scientists and engineers were a part of the conference. Of these, 75 were from the United States and 21 were from foreign countries. In terms of institutional affiliation, 60 were from universities, 23 from government laboratories or offices and 13 from industry. These figures are typical of most previous Gordon Conferences on Physical Metallurgy

PROGRAM HIGHLIGHTS

The highlights of any Gordon Conference are the stimulating environment and the informal scientific discussions which lead to new ideas. Many of the participants indicated that they had developed new ideas which they intended to pursue in the coming months. This is regarded by most as the primary benefit of the Gordon Conference.

The lecture by Vitek set the tone for the first few days of the conference. He discussed the nature of grain boundary structure in terms of grain boundary dislocations. Through subsequent discussions, this served as an introduction to the concept that crystal dislocations can react with grain boundaries to form grain boundary dislocations. Thus the link between crystal plasticity and the structure of grain boundaries was established. This idea took explicit form in Grabski's lecture. He showed that when crystal dislocations run into grain boundaries they gradually "dissolve" and become part of the boundary structure. In this way one can think of crystal dislocations transforming to become grain boundary dislocations. When the dislocations have only recently entered the boundary they are called extrinsic dislocations but when they have completely "dissolved", new dislocations formed are called intrinsic dislocations

because they are part of the structure of the boundary.

Arzt showed that the grain boundary dislocation structure can be extremely important in connection with high temperature creep of particle strengthened alloys. In particular, emission or absorption of vacancies at climbing grain boundary dislocations can be inhibited by the presence of grain boundary particles and this can lead to threshold stresses for diffusional creep.

One of the more exciting developments at the conference was presented by Briant who showed that first principle calculations of atomic configurations which resemble grain boundaries could be used to understand certain aspects of grain boundary cohesion . In particular, he showed that the presence of B tends to "increase cohesion" in Ni based materials while the presence of S tends to have the opposite effect. A limitation of the present technique is that the energy cannot be calculated reliably and that the cohesive strength cannot be determined directly.

Remarkable mechanical properties of multilayered crystals was reported by Tsakalakos. He described composite crystals consisting of alternating layers of Cu and Ni, each about 20-30 Å in thickness. In this dimensional regime the layers are fully coherent and the elastic stiffness of the composite is extremely large. Under some conditions the elastic modulus parallel to the layers is 5-10 times the expected modulus of the two materials. These unusual effects appear to be a consequence of the residual strain states found in these materials.

The classical subject of polycrystal hardening was reviewed at the conference. One new idea that emerged is that the ordinary Hall-Petch plot may indicate not only the effect of grain size on flow strength but

also the effect of grain boundary character. Annealing to produce a given grain size may also determine the character of the grain boundaries involved. This observation indicates the need for careful studies of grain boundary hardening in which the nature and density of grain boundaries are controlled separately.

Another exciting talk was given by Gleiter, who discussed an entirely new class of materials called Nanocrystalline Solids. These materials are made by forming and consolidating extremely fine powders of ordinary metals. Grain sizes are typically a few nanometers (20-30 $\mathring{A}$) in diameter. Under these conditions about half of the atoms in the solid reside in the regions between the crystals. These materials are surprisingly stable and have extraordinary strength properties.

Interfaces play a key role in determining the mechanical properties of microelectronic thin film materials. Some of the most recent research in this area was discussed by Murakami of IBM and Flinn of Intel. These reports represent the first efforts in this area, although this is a rapidly growing area of research for the mechanical behavior community. For many this was the first exposure to the importance of mechanical properties in integrated circuit structures.

Although most of the program focused on grain boundaries, one very exciting talk was given by Nutt on the structure of interfaces in metal matrix composites. It is well known that the mechanical properties of metal matrix composites are determined almost completely by the interfaces between the fiber and matrix phases.

1985 GORDON CONFERENCE ON PHYSICAL METALLURGY

August 5-9, 1985, Holderness School, Plymouth NH

TOPIC: ROLE OF INTERFACES IN DEFORMATION AND STRENGTHENING

*****

Monday, August 5, 1985

SESSION I

GRAIN BOUNDARY STRUCTURE

Session Chairman:

Prof. T. Watanabe
Tohoku University
Sendai, Japan

8:30-9:10 AM	GRAIN BOUNDARY DISLOCATIONS AND ATOMIC STRUCTURE OF GRAIN BOUNDARIES Prof. V. Vitek University of Pennsylvania Philadelphia, Pennsylvania
9:10-9:25 AM	DISCUSSION
9:25-10:00 AM	ATOMISTIC CALCULATIONS AND GRAIN BOUNDARY STRUCTURE Dr. P. Bristowe Massachusetts Institute of Technology Cambridge, Massachusetts
10:00-10:15 AM	DISCUSSION
10:15-10:40 AM	BREAK
10:40-11:00 AM	ATOMIC LEVEL RESOLUTION OF GRAIN BOUNDARIES Dr. W. Krakow IBM Thomas J. Watson Research Center Yorktown Heights, New York
11:00-11:15 AM	DISCUSSION
11:15-11:50 AM	SPREADING OF EXTRINSIC GRAIN BOUNDARY DISLOCATIONS Prof. W.M Grabski Warsaw Technical University Warsaw, Poland
11:50-12:00 noon	DISCUSSION

Monday, August 5, 1985

SESSION II

GRAIN BOUNDARY RELAXATION PROCESSES

Session Chairman:

Prof. A.K. Mukherjee
University of California, Davis
Davis, California

8:00-8:40 PM — EXTRINSIC GRAIN BOUNDARY DISLOCATIONS AND DEFORMATION OF POLYCRYSTALS

Prof. K. Tangri
University of Manitoba
Winnepeg,Manitoba, Canada

Dr. R.A. Varin
University of Waterloo
Waterloo, Ontario, Canada

8:40-9:00 PM — DISCUSSION

9:00-9:40 PM — SLIP INTERFACE INTERACTIONS AT ELEVATED TEMPERATURES

Dr. M.H. Yoo
Oak Ridge National Laboratory
Oak Ridge, Tennessee

9:40-10:00 PM — DISCUSSION

Tuesday, August 6, 1985

SESSION III

INTERFACE CONTROLLED PROCESSES

Session Chairman:

Prof. R. Gibala
University of Michigan
Ann Arbor, Michigan

8:30-9:10 AM	INTERACTIONS BETWEEN CRYSTAL SLIP AND GRAIN BOUNDARIES IN NICKEL Prof. R. Raj Cornell University Ithaca, New York
9:10-9:30 AM	DISCUSSION
9:30-10:10 AM	INTERFACE CONTROLLED DIFFUSIONAL CREEP Dr. E. Arzt Max Planck Institute Stuttgart, West Germany
10:10-10:30 AM	DISCUSSION
10:30-11:00 AM	BREAK
11:00-11:40 AM	GRAIN BOUNDARY MIGRATION Prof. A.S. Argon Massachusetts Institute of Technology Cambridge, Massachusetts
11:40-12:00 noon	DISCUSSION

Tuesday, August 6, 1985

SESSION IV

INTERFACIAL BONDING

Session Chairman:

Dr. B. Kear
Exxon Research and Engineering
Annandale, New Jersey

8:00-8:40 PM	COHESIVE STRENGTH OF GRAIN BOUNDARIES
	Dr. C.L. Briant General Electric Company Schnectady, New York
8:40-9:00 PM	DISCUSSION
9:00-9:40 PM	MECHANICAL PROPERTIES OF MODULATED STRUCTURES
	Prof. T. Tsakalakos Rutgers University Piscataway, New Jersey
9:40-10:00 PM	DISCUSSION

Wednesday, August 7, 1985

SESSION V

POLYCRYSTAL DEFORMATION

Session Chairman:

Prof. R.D. Doherty
Drexel University
Philadelphia, Pennsylvania

8:30-9:20 AM	GRAIN SIZE STRENGTHENING: YIELDING BEHAVIOR Prof. H. Margolin Polytechnic Institute of New York New York, New York POST YIELDING BEHAVIOR Prof. A.W. Thompson Carnegie Mellon University Pittsburg, Pennsylvania
9:20-9:40 AM	DISCUSSION
9:40-10:20 AM	TEXTURE AND MICROSTRUCTURAL EVOLUTION AT LARGE STRAINS Prof. H. Mecking and Dr. J. Estrin University of Hamburg Hamburg, West Germany
10:20-10:40 AM	DISCUSSION
10:40-11:00 AM	BREAK
11:00-11:40 AM	NANOCRYSTALLINE SOLIDS - AN APPROACH TO A NEW TYPE OF MATERIALS Prof. H. Gleiter University of Saarlandes Saarbrucken, West Germany
11:40-12:00 noon	DISCUSSION

Wednesday, August 7, 1985

SESSION VI

MECHANICAL PROPERTIES OF THIN FILMS

Session Chairman:

Dr. D. Gupta
IBM Watson Research Center
Yorktown Heights, New York

8:00-8:40 PM	MECHANICAL PROPERTIES OF THIN FILMS ON SUBSTRATES Dr. M. Murakami IBM Watson Research Center Yorktown Heights, New York
8:40-9:00 PM	DISCUSSION
9:00-9:40 PM	MECHANICAL PROPERTIES OF INTERCONNECT AND PASSIVATION THIN FILMS Dr. P.A. Flinn Intel Corporation Santa Clara, California
9:40-10:00 PM	DISCUSSION

Thursday, August 8, 1985

SESSION VII

GRAIN BOUNDARY SLIDING AND SUPERPLASTICITY

Session Chairman:

Prof. T.G. Langdon
University of Southern California
Los Angeles, California

8:30-9:05 AM	ROLE OF INTERFACES IN SUPERPLASTIC DEFORMATION Prof. B. Baudelet Institut National Polytechnique de Grenoble Grenoble, France
9:05-9:20 AM	DISCUSSION
9:20-9:55 AM	GRAIN BOUNDARY DISLOCATION CREEP Prof. G.L. Dunlop Chalmers University of Technology Goteborg, Sweden
9:55-10:10 AM	DISCUSSION
10:10-10:25 AM	BREAK
10:25-11:00 AM	EVOLUTION OF GRAIN SIZE DISTRIBUTION DURING SUPERPLASTIC DEFORMATION Dr. A.K. Ghosh Rockwell International Science Center Thousand Oaks, California
11:00-11:15 AM	DISCUSSION
11:15-11:50 AM	STRAIN ENHANCED MICROSTRUCTURAL CHANGES DURING SUPERPLASTIC FLOW Prof. D.S. Wilkinson McMaster University Hamilton, Ontario, Canada
11:50-12:05 PM	DISCUSSION

Thursday, August 8, 1985

SESSION VIII

AFTER DINNER LECTURE

Session Chairman:

Prof. B. Wilshire
University College of Swansea
Swansea, Wales

8:30-9:30 PM — SOAP, CELLS AND STATISTICS - RANDOM PATTERNS IN TWO DIMENSIONS

Prof. D. Weaire
Trinity College
Dublin, Ireland

9:30-10:00 PM — DISCUSSION

Friday, August 9, 1985

SESSION IX

INTERFACE EFFECTS IN DEFORMATION AND STRENGTHENING

Session Chairman:

Prof. H. Oikawa
Tohoku University
Sendai, Japan

8:30-9:10 AM	BOUNDARIES AND INTERFACES IN ALUMINUM BASED COMPOSITES Dr. S. Nutt Arizona State University Tempe, Arizona
9:10-9:30 AM	DISCUSSION
9:30-10:10 AM	STRENGTHENING MECHANISMS IN ORDERED ALLOYS Prof. D.P. Pope University of Pennsylvania Philadelphia, Pennsylvania
10:10-10:30 AM	DISCUSSION
10:30-11:00 AM	BREAK
11:00-11:40 AM	DIFFUSIONAL AND SLIDING RELAXATION PROCESSES AT INCLUSIONS Dr. D. Srolovitz Los Alamos Scientific Laboratory Los Alamos, New Mexico
11:40-12:00 noon	DISCUSSION

Poster Presentations

1985 Gordon Conference on Physical Metallurgy

W.D. Nix, Chairman

August 6,7 1985, 5:00-6:00 pm

1. K. Maruyama and H. Oikawa
   Tohoku University
   "Grain Boundary Strengthening at Elevated Temperatures"

2. V. Raman and T.G. Langdon
   Univ. of Southern California
   "Grain Boundary Effects in High-Temperature Low-Cycle Fatigue"

3. J.-L. Martin
   Ecole Polytechnique Federale de Lausanne
   "Interaction of Dislocations and Creep Subboundaries"

4. J.H. Schneibel
   Oak Ridge National Laboratory
   "Grain Boundary Sliding in Metals and Alloys with Bamboo Structure"

5. J. Don and S. Majumdar
   Argonne National Laboratory
   "Creep Cavitation and Grain Boundary Structure in Type 304 Stainless Steel"

6. J.E. Harris
   Central Electricity Generating Board
   "Diffusional Properties of Oxide/Metal Interfaces"

7. M.F. Doerner and W.D. Nix
   IBM and Stanford University
   "Mechanical Properties of Thin Films Using Sub-Micron Indentation Measurements"

8. J.T. Wetzel
   IBM Thomas J. Watson Research Center
   "Computed Grain Boundary Structures in Silicon"

GORDON RESEARCH CONFERENCE

PHYSICAL METALLURGY

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